Chapter 24 Transport of Oxygen and Carbon Dioxide in Body Fluids

1. Solubility of oxygen is low
2. Metalloproteins increase oxygen carrying capacity 50X.
   A. $P_{O2}$ in the blood remains low
   B. oxygen extraction increases

Respiratory Pigments

1. Hemocyanins (Copper)
   A. Arthropods and molluscs
   B. dissolved in the hemolymph
   C. blue when oxygenated

2. Hemerythrins
   A. Brachiopods, some annelids
   B. Contains iron
   C. found inside coelomic cells
   D. violet-pink when oxygenated

3. Hemoglobin
   A. Most common respiratory pigment
   B. Vertebrates, nematodes, some annelids, crustaceans, and insects

3 Hemoglobin

Fig. 24. 1

A. protein globin bound to a heme molecule containing iron
D. Usually carried within Erythrocytes
   a. Hb molecules: small in size
   b. within RBCs
      a) Advantage for solutes, diffusion.
      b) Reduced colloidal osmotic pressure
   c. Chemical environment within cell can differ from blood plasma.
E. red when oxygenated
F. Myoglobin in muscles

Fig. 24.2 Human developmental changes in hemoglobins

Respiratory Pigment Binding of $O_2$

1. Reversible reaction:
   A. $Hb + O_2 \leftrightarrow HbO_2$
   B. $HbO_2 = \text{oxyhemoglobin}$
   C. $Hb_4(O_2)_4$

Fig. 24.4 Oxygen Equilibrium Curves

1. $\% O_2$ saturation of Hb as a function of $P_{O2}$ in the plasma
2. As $P_{O2}$ increases, hemoglobin binds more oxygen
3. Saturation tension for $P_{O2}$ is 95% oxygen saturation.
Figure 24.4  A typical oxygen equilibrium curve for human arterial blood presented in two different ways

5. Relationship between $P_{O_2}$ in the plasma and $O_2$ in a volume of blood
6. Varies with Hb

Oxygen Equilibrium Curves, cont.

Figure 24.5 Shapes of Oxygen Equilibrium Curves
1. Upper part of curve is flat
2. Little effect for PO2 at loading site.
3. high sensitivity at unloading site.

Figure 24.5 Oxygen delivery by human blood at rest and during vigorous exercise
1. At Rest
   A. $P_{O_2}$ 40 mm Hg
   B. 25% of $O_2$ bound to Hb is delivered to the tissues.
   C.
2. Vigorous exercise
   A. $pO_2$ drops to steep part of curve.
   B. 10 more ml of $O_2$ / 100 ml are delivered

Figure 24.6  As the $O_2$ partial pressure of blood falls, less and less of a drop in partial pressure is required to cause unloading of 5 vol % $O_2$

Figure 24.7 Shapes of Oxygen Equilibrium Curves
1. hyperbolic or sigmoidal
2. myoglobin binds oxygen independently
3. Hemoglobin exhibits a sigmoidal curve because of cooperativity
How to measure P₅₀ (Fig. 24.9)

1. Shape reflects a trade-off between loading and unloading O₂.
2. High oxygen affinity = loads more easily = left-shifted curve (decreased P₅₀).
3. Low oxygen affinity = gives up oxygen more readily = right-shifted.

Fig. 24.11 Conditions That Affect Oxygen Affinity

1. Bohr effect or shift
2. A right shift in the normal curve due to decrease in pH and associated increase in CO₂.

Fig. 24.12 Bohr effect typically enhances O₂ delivery

Other Conditions That Affect Oxygen Affinity

1. Temperature (Fig 24.14)
   A. Increases in temperature decrease oxygen affinity; right shift
      a. Promotes oxygen delivery during exercise
Other Conditions That Affect Oxygen Affinity

1. Organic modulators of hemoglobin (e.g., 2,3-DPG [bisphosphoglycerate]) (Fig. 24.15)
   A. Increases in these modulators decrease oxygen affinity; right shift
      a. Helps oxygen unloading at tissues
      b. Increase during exercise or at high altitudes
      c. Pregnant women have a 30% increase in DPG
      d. People with anemia often have a chronic increase in 2,3-DPG
   B. Fetal hemoglobin (HbF) exhibits a low affinity for 2,3-DPG

Box 24.2: Blood Cells and their Production

1. Regulation of RBC production
   A. Erythropoietin (EPO) is secreted by the kidneys in response to low oxygen levels in the blood
   B. EPO stimulates RBC production in the bone marrow

Figure 24.20
When water fleas are transferred to O2-poor water, their O2 transport system undergoes rapid acclimation because of altered gene expression

Carbon Dioxide Transport

1. CO2 is more soluble than oxygen
2. Little is transported in the plasma
3. Some binds to proteins (carbaminohemoglobin)
4. Most CO2 is transported as bicarbonate
5. CO2 + H2O ⇌ H2CO3 ⇌ HCO3⁻ + H⁺
6. Carbonic anhydrase catalyzes the formation of HCO3⁻

Carbon dioxide transport in blood

1. As bloods deliver O2 it picks up CO2
   A. About 50 ml/L of CO2 per trip
2. Little CO2 is dissolved in solution (5%)
   A. pH of the blood would drop from 7.4 to 4.5.
3. CO2 has only a small effect on pH (7.45 to 7.42) due to buffering by carbonates and proteins
Carbon Dioxide Transport

1. 95% of the CO₂ is carried in red blood cells:
   A. About 20% is directly bound to hemoglobin.
   B. 75% is converted by **carbonic anhydrase** into
   C. bicarbonate ions that diffuse back out into the plasma and
   D. hydrogen ions (H⁺) that bind to the protein portion of the hemoglobin

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Carbonic anhydrase and velocity of CO₂-water interaction

1. Carbonic anhydrase is found primarily in RBCs,
2. Reversible hydration reaction of CO₂
   A. carbonic anhydrase speeds up
      \[ H₂CO₃ → H₂O + CO₂. \]

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Vertebrate Red Blood Cells and CO₂ Transport (Fig. 24.23)